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The major objective of this project is to develop the intellectual independence of the student by enabling him to engage in self initiated scientific research. The program is structured so that the student selects an area for investigation, searches the literature, identifies a problem in that area, writes a rationale, designs the study, conducts the investigation, and then analyzes and reports the results. Research ideas, subject matter information, and laboratory and analysis techniques are presented by the staff and/or scientists by means of lectures, seminars and individual or small group conferences. A six-week summer program is conducted beginning with a week long orientation at the University of Pittsburgh followed by two weeks at the University Field Laboratory of Ecology. The student spends the last three weeks of the program conducting his study at or near his local high school. Work not completed during the summer is continued during the academic year. Ninety students and seven teachers, representing 19 schools, took part in the summer program, while 209 students and 14 teachers, representing 32 schools, took part during the school year. (BC)

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FINAL REPORT

PROJECT NO. S–404

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UNIVERSITY OF PITTSBURGH HIGH SCHOOL SCIENCE RESEARCH PROGRAM

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University of Pittsburgh High School Science Research Program

Carolyn A. Gibson

University of Pittsburgh

Pittsburgh, Pennsylvania

July 31, 1968

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

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Summary

The University of Pittsburgh High School Science Research Program, sponsored by the School of Education and with the cooperation of scientists from the Biology Department, Schools of Medicine and Dentistry, Graduate School of Public Health, and from the Community, enables high school teachers and students to learn research procedures by conducting their original scientific investigations. The program is structured to include the selection of an area of investigation, conduction of a literature search, identification of a problem in the area, writing a rationale, designing the sequence of experiment and data collection, conduction of the experiment, analysis and reporting of results. Ideas for research, foundations in subject matter, and laboratory and analysis technics are presented by the staff and/or scientists as lectures, seminars, or individual and small group conferences. The experimentation is conducted at the participating high schools.

A feature of the summer program is an orientation week at the University, at which time lectures, laboratory and library workshops, protocol writing, and progress reports are part of the activity. The purpose is to develop attitudes toward scientific research as well as lay the foundations for sciencing to be conducted at the high schools in the following five weeks.

One phase of the HSSRP, the development of an ecological background for experimentation, includes the orientation week followed by two weeks at the University Field Laboratory of Ecology at Pymatuning Lake. Twelve high school students and four teachers participate. The lectures are presented by the Biology Department and field activities are planned by the HSSRP staff. Students return to the high schools to conduct their original research on school sites or nearby selected areas.

Work that is not completed in the summer program continues into the academic year as class or club activity. Thus more students are motivated into similar activity in the participating schools.

Support for the program is shared by the participating high schools, service organizations, School of Education, and the U. S. Department of Health, Education, and Welfare Office of Education.

During the summer of 1965, 90 students and 7 teachers participated in the six-week program. They represented 19 schools. In the academic year 1965-1966, 209 students and 14 teachers in 32 schools participated in HSSRP activities. They were selected on their interest in the sciences as evidenced by sample protocols evaluated according to feasibility and ideas.

Evaluation of the program is a basic need. A plan for determining the outcomes is included, and will be implemented. Another problem that needs study is that of "grading" the students who are conducting research activity in class. A plan for self-evaluation by students as well as by teacher and scientist-advisor is included.

University of Pittsburgh High School Science Research Program

Rationale for a Research Program at the High School Level

Knowledge in the sciences is doubling every ten years. This is due to the scientific research that is being reported. Because of this increase in knowledge, it is becoming increasingly difficult for science teachers to maintain an adequate foundation in any scientific area, leading to inaccuracies in information. One solution to the dilemma is to change teaching methods from emphasis on factual information to an emphasis on procedural learning.

The dominant aim in education should be to develop the intellectual independence of each student to the fullest extent. After a formal teaching sequence has developed certain abilities in the student, the student must have a way of using these abilities to explore his own interests. When the responsibility for learning has been placed with the student, where it belongs, and with the teacher directing student activities and using qualified personnel from the community whenever necessary and appropriate, this aim may be realized.

Emphasis by the teacher on breadth of experience, analysis, criticism, evaluation, interpretation, and communication, leads to and depends upon the acquisition of factual knowledge. When given the opportunity to try to discover unknown truths, or to question facts through problem solving activities, students respond by learning facts and technics in more detail than is required by the teacher. The discussions and questions that result are evidence of intellectual development.

Individualized instruction presents the opportunity for young people to develop according to their abilities, aptitudes, and interests. In science education at the junior and senior high school levels, the use of original scientific investigations as educational methodology presents a challenge to both teachers and students, and utilizes both procedural and informational learning by the individual. It also enables each student to progress according to his abilities and interests.

A program of scientific research participation by high school teachers and students has been conducted in a number of high schools in the Pittsburgh area in cooperation with the University of Pittsburgh since 1959. This activity uses the standard approach of selection by the student of an area for investigation, literature search, protocol writing, experimenting, discussing progress, statistical evaluation, and final reporting with direction by the teacher and with the advice and supervision of scientists.

Lectures of ongoing research from which ideas may be investigated are presented by scientists at the University of Pittsburgh or at participating high schools at various times during the year, both during the summer and academic year. Other seminars are presented on methods of scientific investigation, design of experiments, methods of data collection, laboratory technics, and statistical evaluation.

The participants select an area for investigation, survey the literature for background of the known and the unknown, and develop a problem from the readings, lectures, or from observations. The literature is again surveyed for information pertinent to the problem: what scientists have worked on this or a related problem; what has been learned. This information is now organized into a protocol, which includes the title, rationale, which includes an hypothesis, sequence of experiment, planned data collection, materials list, and bibliography.

The protocols are presented to the teacher and/or director of the program for evaluation. This evaluation at this stage is primarily for feasibility of ideas, and suggestions are made for improvement. As soon as the protocol is approved, a scientist is contacted to serve as advisor. He may make suggestions for further reading or changes in design. When the scientist, teacher, and young researcher concur in details, the needed technics are practiced, materials ordered, and experimentation is begun.

The accessibility of reading materials for a literature search is a problem in many schools. Textbooks and encyclopedias are first surveyed, followed by a survey of technical books and periodicals at the high school. Community libraries are utilized, and for those students close enough to the University, identification cards are issued which enable them to use the Laura and Maurice Falk Library, School of Medicine, and the Langley Library of the Biology Department. The Technological Section of Carnegie Institute Library is also widely used by the teachers and students.

Plan of operation

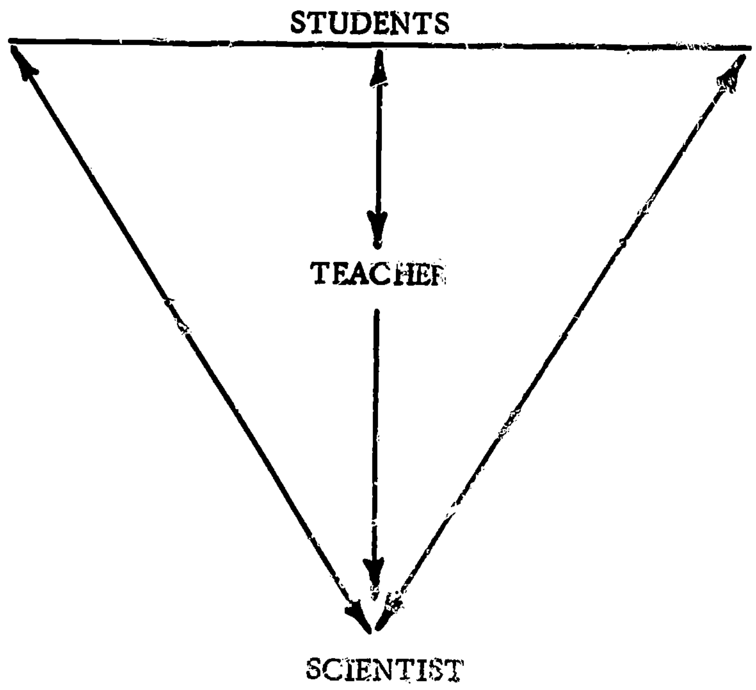
(1) Introduction

Cooperation is the key to the successful operation of a scientific research program in the high school. Understanding and approval of the plan by scientists, administrative staff, teachers, students, parents, and custodians aids in securing this cooperation in the school and community. Instituting the investigative approach to teaching in a school involves conferences with administrators and school board members, faculty discussions, parents' nights, assembly programs, class discussions, and requests for aid from custodians.

(2) General Design

Student - Teacher - Scientist Relationship

The inverted triangle is a symbol of the cooperation involved in the University of Pittsburgh High School Science Research Program. The broad top, labeled "Students", indicates that the activities are student oriented, that is, each student or small group of students, selects and plans the problem to be investigated, with teacher direction. If the student needs more specialized help than the teacher can give, arrangements are made for a scientist to give advice to both the teacher and students. In his advisory capacity, the scientist may help with the selection of the area for investigation, the plan of the experiment, direction on learning special technics, and discussions of progress during the conduction of the experiment.



Misinterpretation of the term "student oriented" may lead to the belief that the student is to be allowed complete freedom in his investigation of a scientific problem. Student orientation really means that the opportunity to conduct original scientific research is presented by the teacher, and the students use the same procedures as research scientists.

(3) The Role of the Teacher

The role of the teacher in the program is that of director of students and their activities. As such, the teacher must understand research procedures, be able to adapt as many as possible to the school situation, and to use community resources to supplement the school facilities when necessary. The following guides or procedures assist teachers to adapt the procedures in an ideal educational situation that exists during the summer program into the academic year, either in class or club activity. The degree of success of research activity in the school is dependent upon the teacher.

The teacher may also be a researcher and have students become motivated through interest in observing procedures and discussions of the teacher's protocol. This often leads to new ideas for investigation by the student in the area of interest of the teacher.

<u>Procedures Used by Teachers in Directing Students in Research Activity</u>*

1. Attends lectures and seminars by scientists and directs discussions on ideas for research from them.

2. Presents opportunities for students to use the high school library for sources of ideas for research problems and for background information in the areas selected.

3. Lectures on how to use the library and how to search and abstract literature.

4. Arranges for students to use community and college and university libraries for a complete literature search.

5. Directs discussions by students on abstracted materials.

6. Conducts or arranges for sessions on methods of scientific research and on past and present research in various scientific areas.

7. Confers with individual and/or small groups of students with similar interests to develop procedures to follow in writing the scientific plan or protocol:

   a. Formulation of definitive title
   b. Development of basic information leading to understandings
   c. Discussion of scientific style of writing the rationale
   d. Selection and practice of laboratory technics
   e. Decisions on methods of experimentation to be used
   f. Emphasis on data collection, observation, and measurement technics

8. Lectures or plans seminars (teacher or advisor) as needed for background information

9. Arranges for conferences with scientists when students need more technical advice than the teacher can give, or when the protocol has been approved by the teacher and is ready for discussion with the scientist

10. Schedules and directs progress reports to develop:

    a. Better understandings of scientific principles

*Carolyn A. Gibson, Joseph H. Sunder. <u>Handbook of Research for High School Students and Teachers</u> 1965 - pp. 8-11. (Unpublished)

b. Appreciation of problems encountered in original investigation through exchanges of ideas, procedures, and evaluations

c. Improved oral communications

d. Reasoning and interpretation

11. Approves protocols for presentation to the scientist-advisor. A checklist of items for approval follows:

    a. Idea for investigation (title)

    b. Background material with evidences of reading and reason for conducting the experiment (rationale)

    c. Experimental design

    d. Data collection plan

    e. Materials list

12. Helps collect materials needed after approval of protocol; encourages ingenuity in students.

13. Instructs students in proper laboratory technics and supervises experimental procedures.

14. Reviews records of data collection. (Records are kept in duplicate, with student keeping data book and giving a <u>carbon</u> copy to the teacher so that direction by the teacher is maintained without interference with the experimental progress of the student researcher.)

15. Checks abstracts of the literature searched to maintain high standards of reading. (The abstracts are made in duplicate so the student researcher has his notebook for reference at all times.)

16. Conducts discussion on statistical evaluation of results or arranges for such discussion.

17. Instructs in preparation of the final reports.

18. Plans summary sessions upon completion of problems. Tape recordings of these sessions are advantageous.

19. Evaluates student progress through the total research procedures, gains in personal development, and growth in fundamental knowledge.

20. Files copies of protocols and final reports for reference by other students.

21. Presents final reports for publication if possible.

Teachers are oriented to the activities through consultation with the staff at the school or University, attendance at seminars, and through regularly scheduled teachers meetings. Some topics that have been considered in these meetings include:

1. Evaluation of students other than by tests

2. Use of the Handbook of Research for High School Students

3. Problems in participating schools

4. Foundations for research for junior high students

5. Laboratory and research technics

6. Procedures allowing for creativity

(4) The Student Researcher

The outline titled "Method of Original Scientific Investigation Used by Students" was developed as an aid for both teachers and students. Detailed explanations are given in the Handbook for High School Students and Teachers which is made available to all participants.

Method of Original Scientific Investigation Used by Students*

I. Selects an area of interest.

A. Surveys the literature.

1. What is known
2. What is unknown
3. Keeps record of all readings

B. Concentrates on part of area.

1. Readings become specialized
2. Discusses interesting ideas with teachers and advisors to develop unknowns or questioned items.

II. Formulates a research problem.

A. Definitive title

B. Read for background of specific problem

1. Related problems: who worked on these; what methods were used; what was learned?
2. Laboratory procedures needed

*Carolyn A. Gibson, Joseph H. Sunder. Handbook of Research for High School Students and Teachers 1965 - pp. 13 & 14. (Unpublished)

III. Writes the rationale in scientific style.

A. History of related and previous experimentation

B. Ongoing research in the specific area

C. Analysis of unknowns and questioned items

D. Reason for conducting the experiment

IV. Plans the experiment

A. Makes choice of methods

B. Sequence of experiment

1. Accurate, brief, complete steps to follow
2. Attach copies of laboratory technics to be used

C. Data collection

1. Design data sheets

2. List types of observations to be made

D. Materials list

1. Quantities and specifications

2. Resourcefulness and ingenuity will supply many needed items

V. Discusses protocol and changes as needed for approval.

A. Teachers, scientists, other students

VI. Conducts approved experiment.

A. Follow protocol exactly: if changes are necessary, write addendum, have approved, and attach to protocol.

B. Record all observations

C. Measure accurately and record

D. Discuss observations during experiment

E. Analyze data statistically

F. Interpret data using statistical analysis

VII. Final report

A. Title

B. Rationale
1. Pertinent information added to original during progress of study.

C. Protocol

1. Sequence of experiment
2. Addenda describing changes made
3. Data and analysis (graphs and tables)
4. Observations
5. Materials list

D. Discussion of results

E. Conclude or repeat

F. Literature cited

1. Refer to literature in rationale and discussion
2. Use references applicable to the problem

(5) The Scientist in High School Science Research*

The cooperation of the participating scientists made possible the development and continuation of the science research program for high school teachers and students. These scientists have given generously of their time and talents in presenting lectures, conducting seminars, and serving as advisors. The inspiration received by these potential young scientists through these activities cannot be measured.

It should be noted that the time of the scientist is valuable, and that conferences, lectures, and seminars by the scientist must be carefully scheduled. The student and teacher must evaluate the progress of the investigation and ask for conferences or write letters giving specific reasons for requesting the assistance of a scientist only when applicable. The attitude shown by a statement "tell me all you know about feathers" should be replaced by "in my study of feathers, I found that feathers will change under certain conditions, and my proposed investigation concerns the effect of . . . "

Procedures followed by various scientists include:

1. Lectures on ongoing research in the area of interest of the scientist to students and teachers for a) development of broad information background and, b) for ideas of original scientific investigation.

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*Carolyn A. Gibson, Joseph H. Sunder. Handbook of Research for High School Students and Teachers 1965 - page 12. (Unpublished)

2. Advises individuals or small groups of students and teachers interested in his area of specialization. Some areas discussed include a) understanding of the problem and its rationale; b) design of experimentation; c) plan of observations and data collection; and d) reading done with suggestions of other sources of information. The safest and most applicable procedures in conducting the experiment are considered. Following the actual experimentation, methods of evaluation of the investigation are applied.

3. Participates in progress report and summary sessions to help direct the thinking of students and teachers.

4. Conducts ancillary seminars on technical topics with students and teachers who have studied these topics and wish to know more through questioning the scientist.

(6) Orientation Week

In June, a week of orientation was scheduled at the University of Pittsburgh, after which students and teachers returned to the participating high schools to conduct their experiments, record data, continue reading, give progress reports, and evaluate results. (The ecology group selected to attend the sessions at Pymatuning spent the next two weeks at the Field Laboratory and then returned to the high school research centers to begin their experiments.)

Ninety students from nineteen schools and seven teachers participated. The program included lectures on ongoing research and workshops on procedures. The lecturers were from the University of Pittsburgh School of Medicine, School of Dentistry, Biology Department, Carnegie Institute Museum and Library, Westinghouse Research Laboratories, Bausch and Lomb and American Optical, City of Pittsburgh horticulture department, and Pennsylvania Vision Institute and the staff of HSSRP.

The program was planned to fit the needs of the prospective researchers as indicated by the preliminary protocols presented by students as the criteria for acceptance to the program. They included the categories of nutrition, microbiology, cancer, behavior, immunology, plant and animal growth, genetics, molecular aspects; and ecology.

The purposes of the orientation week are:

1. To observe how scientists work through lectures and seminars describing ongoing research; conferences between scientists and student/teacher researchers for advice in revising protocols; and evaluating progress reports by students describing planned experimentation and exchanging information and ideas.

2. To understand the entire research problem through writing and revising protocols which includes designing the experiment, planning data collection, learning statistical methods for evaluation, practicing laboratory technics, keeping notebooks and data books, procuring materials, presenting written and oral progress and final reports.

3. To learn and practice correct library usage by locating pertinent information, abstracting, reporting, and keeping a bibliography.

(7) Centers for Research, Summer Phase

A. School Activity

In the 5 weeks following the orientation week, the program was conducted in the participating high schools. This included final revision and approval of protocols, learning needed laboratory technics, procuring materials for the experiments, conducting the experiment, collecting and analyzing the data, and preparing the final report.

Progress reports, continued reading in the area for investigation, and instruction by the teacher and laboratory assistants leading to development of concepts, and discussions between peers were other activities included in the summer phase.

Student researchers conducted their work from 9:00 to 12:00 A.M. each day, Monday through Friday. If conditions required work in the afternoons, or on Saturdays and Sundays, special arrangements were made by the student through the teacher, who completed arrangements through the school office. If the teacher could not be with the students during these sessions of extra work, the Director's office was notified 24 hours in advance so that a laboratory assistant could provide the necessary direction and supervision.

Seminars, progress reports, and conferences with advisors were scheduled at least one afternoon a week at the University. The school, community, and University libraries were utilized at this time, also.

B. Workshop in Animal Tissue Culture

During July, Dr. Bruce Casto, epidemologist at the Graduate School of Public Health, volunteered to conduct a workshop in animal tissue culture in his laboratory. Four teachers and eight students participated in the afternoons for two weeks in this program. It was very effective, and four studies involving tissue culture technics were conducted at the participating high schools. Equipment and supplies from the University were loaned to the schools until they could procure their own.

C. Ecological Investigations in the High School Science Research Program

One phase of the total program has been the development of research activity in the area of ecology. During the summer of 1962, a field trip was conducted to the University of Pittsburgh Pymatuning Laboratory of Field Biology. Approximately 120 students and teachers participated in this overnight trip (NSF supported).

During the summer of 1963, seven high school students and two teachers from the University of Pittsburgh High School Science Research Program (NSF sponsored) spent two weeks at the Field Laboratory on an experimental basis and then returned to the participating high schools to continue their investigations. The students demonstrated their abilities to conduct ecological research and the teachers received training which enabled them to improve the curriculum of biology in their schools.

The following year, 1964, through a grant from the Pittsburgh Foundation and with the cooperation of the staff of the Field Station and the University Biology Department, a laboratory building at Pymatuning was made available to the high school group for two weeks each summer. There is sufficient work and storage area for 12 students and 4 faculty members.

This program was supported in 1964 by local school boards, the Buhl Foundation and NDEA Title III, and operated under contract with the Pennsylvania Department of Public Instruction. In 1965, support was provided by school boards of participating districts and by a small contract with the U. S. Office of Education, Health Education and Welfare. (Contract OE-5-10-369).

The objectives of this phase of the program are four-fold:

1. To develop better teaching and learning procedures in science through the use of original scientific investigation by high school teachers and students.

2. To develop the ecological approach to the teaching of biology through training high school teachers and students in ecological technics at the University of Pittsburgh Biological Field Station, Linesville, Pennsylvania. The implementation of BSCS Green Version is included in this objective.

3. To develop good attitudes toward conservation and natural resources and the biology of the environment.

4. To improve facilities and usage of the laboratory and the library by transferring problems suggested through observation into original scientific investigations.

Past experience with the high school groups at the Field Station has led to the development of a plan for developing ecological centers at the various high schools. It was found that there was insufficient time to learn needed technics and to conduct original investigations in the two weeks that the facilities are available to the high school group. It was decided to use the Pymatuning facilities for learning technics, and to conduct the experiments in or near the high school centers. Those students who wished to conduct planned studies at the Field Station could do so, and the continuing study of turtle populations and territories is reported in the appendix.

The ecology of land masses was emphasized during the 1966 program. Recruitment of students was accomplished by conducting seminars in ecology by the staff at the high schools and at the University in May, 1966. Student participants were selected on the quality of idea for original investigation as indicated in evaluation of protocols. Those teachers whose students are accepted were eligible for participating at Pymatuning.

Surveys of school property or nearby areas suitable for ecological studies have been and are being conducted. These areas are the outdoor laboratories. At Fox Chapel Area High School, the school grounds are being used for collection of materials, and both the grounds and the school laboratories are utilized for original investigations in ecology.

(8) Centers for Research, Academic Year

Through class and club activity, interested students continued their original investigations in the participating schools. Several students in each school were motivated to begin such activity, especially through the clubs. Seminars, laboratory workshops, progress reports and summary sessions were scheduled at the schools as well as at the University of Pittsburgh.

A lecture on Ideas for Research Problems in Biology was presented by Dr. Jerome Metzner on November 13. Total attendance: City of Pittsburgh 57, Suburban schools, 258 students.

One group of ten lectures was scheduled for Christmas vacation week, and was attended by one hundred eighty-five students.

Assembly programs were held in two schools for the purpose of disseminating information to the student body and to present the opportunity for students to communicate with their peers. More information is found in the appendix.

(9) Development of Science Curricula

A. Introduction

Any exemplary and innovative program that has been developed through summer sessions and that demonstrates improved interest in learning by students, and enthusiasm for the methodology by teachers, should be adapted into the regular academic curriculum. The idea for the current program was first developed at West View High School (now North Hills) in suburban Pittsburgh. The stated purpose of a class in second year biology (1938) was to help those students who have a special interest and ability in biology to develop basic understandings and technics in solving biological problems. The High School Science Research Program developed when two scientists at the School of Medicine became interested

in the genetics, nutritional and cancer work of the second year biology students and offered their services as advisors (1957-1958). Although North Hills High School is not currently participating in the program, two teachers there are continuing the research method of teaching the two classes in second year biology. In addition, Baldwin, and Fox Chapel Area and Quaker Valley High Schools are using the same approach.

Observation of the interest and excitement in learning by students conducting original investigations led to investigation of the possibility of using research procedures in first year biology classes. Two pilot studies were conducted at North Hills. One class was composed of tenth grade students with a mean IQ of 120. A three-phase arrangement was used, in which the first was instruction in research procedures; second, development of understandings in biology; and third, technics needed for research. The Nelson Achievement Test in Biology was administered at the end of the year, and the median score was the 98th percentile. It should be noted that the instructional materials in the usual academic biology course were not completed.

The following year, two teachers tried the research method in biology class in the same school. Each teacher had 4 classes, three beginning biology (10th grade) and one second year biology (11th - 12th grade). It was decided that two of the academic classes (one for each teacher) would learn by the research approach, and two other classes would use the usual academic approach. Results on the same test (Nelson Achievement Test in Biology) showed one research group scored a median 99 percentile, one a 98 percentile, and the two academic groups, median 98 percentile. It can be tentatively stated that the research approach to teaching first year biology did not harm the students, and their interest in the subject was at a very high level.

B. Research Science with Emphasis on Biology

Teachers in two schools are now developing a course in 9th grade biology using the method described in the paragraphs above. Falk School, a non-profit private school affiliated with the University of Pittsburgh, extended their offerings into the 9th grade in 1965-1966. West Mifflin South High School is the second, and is in an industrial area near Pittsburgh. The ninth grade course was the result of a summer program in the West Mifflin district. Administrators in both schools wish to continue this activity.

In addition, Bethel Park is scheduling a course in Research Science (11th and 12th grades) that is an outgrowth of their summer program (1965).

A table showing the outline of work for approximately the first semester is included in the appendix. This includes the three column design, in which (1) procedures of research are taught with some historical background of the development of science through research and (2) analysis by students of the scientific understandings needed to conduct

original investigation, followed by planned activities to achieve these understandings, and (3) the teaching of technics necessary for understanding of concepts and of research activity. At some point in the year's work, the individual students start their own investigations. The teacher is responsible for the direction of these problems, the clarification of related materials, and the teaching of laboratory technics. Advice by scientists is available.

C. Foundations for Research Activities: A Junior High School Program

Seventh, eighth, and ninth grade students are capable of conducting original scientific investigations. They show many of the traits needed to develop a scientific attitude: strong interest in the sciences, curiosity, resourcefulness, imagination, and willingness to work. These traits, and others, need proper development so that creativity and curiosity are not stifled, and responsibility and honesty are developed. Selection of student oriented activities involving observation, measurement, and interpretation presents an opportunity for training young people in these traits in an action program leading to the solving of original problems.

In general, the aims of the junior high school are to enable these interested students (1) to critically evaluate a problem, (2) to devise a method for finding a solution, (3) to solve the problem, or at least to collect information concerning it, and (4) to be able to draw a conclusion from the data and other information gathered, leading to further inquiry.

Past experience (Avonworth, Baldwin, and Brentwood High School Summer programs) has shown that the program has promise in fulfilling the expressed aims. Evaluation of results shows that a unifying theme is advantageous in planning the summer work, and the curriculum materials produced could be used in the regular science classes in the junior high school. The junior high school group at Avonworth High School therefore, use activities that assist in the development of concepts of growth, including the applications of chemistry, physics, biology, geology, and mathematics. Method to be used.

1. Descriptive and analytical situations will be utilized.

2. The students will observe, measure, and interpret the various phases of science in these situations.

3. Student notebook work will be emphasized to familiarize the student with note taking, data collection, data processing, recording of laboratory procedures, and library work.

4. Laboratory exercises will be provided to motivate the student to develop precision and accuracy in making observations, measurements, and interpretations.

5. Activities in growth will be related where possible to the student's interests, hobbies, and capabilities.

6. A simple research problem for solution near the end of the summer will be a student goal.

(10) Facilities and Equipment

The participating schools are in most cases well equipped for the usual curriculum needs in the sciences. It is planned that each laboratory classroom being used will be further equipped for the kinds of investigation being conducted in that school so that it will become an ideal research center. For example, in a school without a greenhouse and/or animal room, the emphasis might be on such problems that can be studied through the use of tissue culture. For those schools with greenhouses and animal rooms, they will be equipped with controls for temperature, humidity, and light, and technics of proper use will be made available.

The libraries in the schools are in need of more technical science materials than are currently available. A library list is being compiled for such materials, and will be implemented through the centers.

The use of the University libraries will continue for those students who have exhausted the local library facilities. An identification card entitles them to check out books in both the Laura and Maurice Falk Library, School of Medicine, and the Langley Library, Biology Department, University of Pittsburgh. It is also an entry for the Carnegie Technological Library for students.

IDENTIFICATION CARD
School of Education
Addison H. Gibson Laboratory
University of Pittsburgh and Cooperating
High Schools in Science Research

NAME ______________________________

____
High School Affiliation

Date of Expiration ______________________________

____
Director of Cooperative Research

____
High School Science Teacher

(11) Staff

A. Duties of the Director and Associate Directors

The entire program is based upon cooperation between the School of Education, University of Pittsburgh, the personnel of the participating school districts and the scientific community. The major responsibility of the directors is to organize and coordinate activities for the schools to realize the potential benefits.

The present director, Mrs. Carolyn A. Gibson, has worked since 1959 as the co-developer of the research method of teaching. She was co-director from 1959 to 1963 of the University of Pittsburgh High School Science Research Program.

The duties of the assistant directors include the implementation of the program activities as planned in conferences with the director. Each has a specific area of responsibility.

For the summer program, 1965 and academic year 1965-1966, Mr. John Bacon had the responsibility of assisting student researchers with problems involving several scientific disciplines. He lectured at the Research Centers as necessary on such topics as measurement, understanding of solutions, and instrumentation.

The assistant director in charge of the ecological center development was Miss Beulah Frey, who is currently biology teacher at Fox Chapel Area High School. She and her students have participated in the program since 1960, and she has been a leader in the ecological activities at Pymatuning, at her school and adjoining schools.

The actual implementation includes organization of the following activities:

1. Instruction to students and teachers on methods used in original scientific investigation, including library usage with permission to use the University libraries, as well as procedures in protocol writing, experimental design, and laboratory technics.

2. Lectures and seminars on ongoing research, technics, background information to teachers and students presented by scientists. These seminars were presented on Saturdays in the spring, during orientation week in June, once a week during the summer program, and as applicable in the academic year.

3. Evaluation is made of protocols written by students for idea feasibility, background information, and design of experiment. For those students who need more specialized help, assignment of scientist-advisors is made.*

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*See p. 20.

4. Student research procedures are directed by the teachers, with advice by the scientists to both students and teachers.

5. Progress reports and summary sessions are conducted at the University and at the High Schools during the summer program and the academic year.

6. Conferences between the small groups of students and teacher and the scientist-advisors are held as needed.

7. Instruction in statistical evaluation and preparation of final reports is given.

8. Development of a program of instruction in foundations for research activity for junior high school students is presented. This is conducted as a summer school activity, with a follow-up of science club participation in the academic year.

9. Methods to evaluate students involved in this research activity as well as evaluation of the program.

10. Opportunity to study ecological procedures for a two-week period in the summer at the University of Pittsburgh Biological Field Station given to selected students and teachers, followed by research in ecological centers at the high schools.

11. Supervision of the expenditures is the duty of the director, with a continuing inventory of material needs in the centers being maintained.

B. <u>Duties of Laboratory Assistants</u>

Past experience in the program shows that college students who are majors in the sciences have much to contribute to the success of the program. These young people are interviewed to determine their attitude toward the type of learning involved in the High School Research Program, and toward high school students. They are selected on the basis of the interview and a written statement of why they wish to work in the program.

The duties of the laboratory assistants:

1. Library usage
2. Laboratory technics
3. Procuring materials
4. Conferences on understandings
5. Evaluation

It is expected that there will be one laboratory assistant for each school center, with two who will travel as needed for special duties such as statistical evaluation or experimental design.

C. Professional Staff of Lecturers and Advisors

1. Biological Field Station at Pymatuning Lake and Academic Year in Ecology.

C. A. Tryon Jr., Ph.D., Professor of Biology, Natural Sciences Department, University of Pittsburgh, is director of the Pymatuning Laboratory of Field Biology. Dr. Tyron, like the rest of the staff and students at the field laboratory is primarily interested in studying the ecosystems of the Pymatuning area. He has chosen to specialize in the study of one aspect of the ecosystem, the vertebrates, particularly fish and small mammals. His most recent research has been on the dynamics of the chipmunk population at the laboratory.

Richard T. Hartman, Ph.D., Associate Professor of Biology, Department of Natural Sciences assists with the planning of seminars and arrangements at the Field Station. Dr. Hartman's research at the field lab is concerned with aquatic primary producer organisms -- phytoplankton and aquatic vascular plants. Using elodea and coontail, he has been measuring the rate of carbon fixation (photosynthesis) by measuring the rate of uptake of C^{14} in the plant and studying the formation of gasses in the plants. He conducts studies at Sanctuary Lake, Twin Ponds, Conneaut Lake, Crystal Lake, and Linesville Creek in order to inclue several types of aquatic environments.

Gaylord Rough, Ph.D., Assistant Professor of Biology, Alfred University, is Director of the High School work at Pymatuning. Dr. Rough's research has been concerned with the bioenergetics of vertebrates -- their metabolism and its relation to the environment. The problem of measuring the metabolism of the animal in a free environment is basic to this research and Dr. Rough has approached it in two ways. One method is to analyze the animal's food materials by calorimetry. The other is to study the respirometry of the animal in the lab in relation to the biological half-life of trace elements in its environment and then to try to relate information thus obtained to the half-life of trace elements in the natural environment. (Biological half-life refers to the time necessary for half of a material used by the organism to be lost through biological processes such as excretion.)

Kenneth W. Cummins, Ph.D., Assistant Professor of Biology, Natural Sciences Department serves as lecturer and advisor to the high school group. Dr. Cummins is conducting research in three different areas. The first is stream ecology, including such aspects of the stream ecosystem as food chains, mineral cycles, physical and chemical parameters, densities of organisms, and the energy relations of the organisms and environment. The second area of Dr. Cummins research is plankton -- in particular, predatory crustaceans in Sanctuary Lake. His third area of interest is in the study of the behavior of invertebrates -- for example, the case-building behavior of caddisflies.

The graduate students who are conducting research also assist the students at Pymatuning.

2. General Research

The following list of scientists participate by appointment as needed. If there is a student problem for which they do not feel qualified, referral is made to an associate who is a specialist in that area of investigation. In addition, scientists from industry, hospitals, and Carnegie Museum have assisted as necessary.

Axelrod,A. E., Ph.D., Associate Dean, School of Medicine. Lectures on research in nutrition.

Blomster, Ralph N., Ph.D., Assistant Professor of Pharmacognosy, School of Pharmacy. Advisor on allergies.

Brinton, Charles, Ph.D., Professor of Biology, Division of the Natural Sciences. Advisor and lecturer in microbiology. Assigns one student to research in his laboratory during the summer.

Cartwright, T. E., Ph.D., Associate Professor Biophysics and Educational Biophysics, Division of Natural Sciences. Lectures on molecular aspects of the cell. Advises on topics of biophysics.

Casto, Bruce C., Sc.D., Research Associate Epidemiology and Microbiology, Graduate School of Public Health. Lectures and advises on problems in animal tissue culture.

Koritz, Seymour B., Ph.D., Associate Professor Biochemistry, School of Medicine. Ancillary seminars to answer student questions.

Langkamp, Herman, Graduate Student, Microbiology, School of Dentistry. Plant Tissue culture.

Leighton, Joseph, M.D., Professor of Pathology, Medical Pathology Department. Advisor.

Lipson, Joseph I., Ph.D., Research Associate Professor, Learning Research and Development Center. Physics and Geology.

Miller, Erston V., Ph.D., Professor of Biology, Division of Natural Sciences. Lecturer and advisor, Plant Physiology.

Moses, Campbell, M.D., Director, Addison H. Gibson Laboratory, School of Medicine. Lecturer on Research.

Platt, David, Ph.D., Associate Professor Microbiology, School of Dentistry. Lecturer and advisor, Immunology.

Sunder, Joseph, Research Associate, Addison H. Gibson Laboratory, School of Medicine. Lecturer and advisor, experimental design, statistics, and general genetics.

Wachs, Harry, O.D., Pennsylvania Vision Institute, Pittsburgh, Pennsylvania. Lecturer and advisor, Research on Problems Involving Eyes.

Contacts with various scientists in industry are always available. For example, Mr. Arthur Margulies of the Westinghouse Astro-Nuclear Laboratory makes appointments for the student researchers to visit various laboratories and to confer with scientists in the area of investigation. Mr. Jere Keiser, development engineer of Jones and Laughlin Steeland Dr. Robert Spooner and Dr. Don Harrison of the Regional Industrial Development Corporation supply similar services.

(12) Project Evaluation

A. Subjective Plan for Evaluation of the Program

Student Comments.

Any innovative program has problems to be solved, and especially the one of its value to education. As this program developed, students and teachers were asked for their opinions concerning the values of the activities, and these were considered in making plans for the further development of the program. Some of the comments from students at the close of the orientation week follow:

"During the week I have learned more about my project through library work and interviews with scientists. Also, I have greatly increased my knowledge of scientific technics used in a lab for different experiments. The lecture that was given on blood has greatly enlarged my knowledge of the subject even though this does not have much to do with my current problem."

"Discussion of my experiment with advisors has given me a broader view of it. I now realize that genetics is quite pertinent to an investigation of methods of reproduction in Daphnia."

"Thank you so much for this inspiring week. I truthfully think that I have learned more this week than in any other. I have learned perseverence and not to become discouraged if I can't find an answer to my question in an encyclopedia. The lectures, especially Mr. Casto's have been very helpful. Thank you again for the chance to explore a new field of learning."

Many of these comments are repeated year after year by different students. It is important, however, to have young people express their thoughts and feelings concerning their activities. Students will be asked for their critical comments concerning orientation week and other phases of the research activity.

B. Teacher, Laboratory Assistant, Parent, Scientist

The comments from teachers are usually more critical of procedures, and many suggestions for improvement have been made, most of which have been followed. The critical discussions by teachers of conduction of the program were held in meetings and in conferences with the Directors.

The laboratory assistants (college students) also give pertinent comments on the good and bad features of the program from their experiences during the summer. These comments contribute to program improvement where feasible.

Parents of participating students have given verbal comments on the growth and happiness of their children. A check-list needs to be compiled for their use which should give some indication of social progress or lack of it among the students.

Scientist-advisors have made many suggestions for changes in the program. These have been invaluable in the past and a check-list will be given them for assistance in evaluation of the program and the students and teachers in it.

(C) An Objective Evaluation Plan*

Acknowledgement.

The design of this evaluation was aided greatly by people who were generous with both their time and their materials. The author wishes to thank Dr. William Cooley, Director of Project Talent; Dr. Richard Cox of the Learning Research and Development Center; and Dr. Philip R. Merrifield, Director of the Bureau of Educational Research at Kent State University. In addition, suggestions from Mrs. Carolyn Gibson, Director of the High School Science Research Program, were very helpful in directing the evaluation at the critical areas of the research program.

Walter Jesteadt

(D) A Plan for an Evaluation of the University of Pittsburgh High School Science Research Program

1. Rationale

A detailed objective evaluation is necessary to answer the many questions generated by the form of teaching used in the High School Science Research Program. Information from the evaluation can be used to determine what type of students the program should accept or actively seek, what benefits and hazards accompany this form of teaching, the characteristics teachers must have to properly use this form of teaching, and the proper position of the program in future high school curricula.

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*This plan was developed by Walter Jesteadt, one of the student laboratory assistants, a psychology major at Johns Hopkins University, and a graduate of the University of Pittsburgh High School Science Research Program. The work was edited by the Program Director. The plan will be studied and implemented in succeeding years.

The present nature of the program severely handicaps adequate evaluation and explains the lack of objective evaluation up to this time. Presently, this teaching method is being used in some form in approximately fifty schools in the Pittsburgh area (12). However, there are very few schools in which the research approach is a basic part of the science curriculum. In the majority of cases, research work is done in science clubs or independently by students, and the number of students involved is small. This causes difficulties in establishing uniform testing procedures, in arranging for adequate control groups, and in establishing clear criteria for deciding which students are being taught by the research method. Participation in the program is voluntary and there is subjective evidence that the participants differ significantly from the general high school population and from the population of college-preparatory students. This means that the data collected will not represent a random sample and may not be an adequate basis for decisions about the advisability of widespread curriculum changes.

In spite of these handicaps, it is possible by observing students taught by the research method to generate several hypotheses which can be investigated by an objective evaluation.

The fundamental hypothesis is that the value of this method lies in its close relationship to methods recommended for fostering creativity. A theoretical background for the program has been independently established by the leaders in the growing field of creativity testing and research. Torrance defines creativity as 'the process of forming ideas or hypotheses, testing hypotheses, and communicating the results'(29). By this standard the research program represents an individual exercise in creativity for each of its students.

A subjective evaluation of the program can be made by comparing conditions in it with conditions psychologists recommend for fostering creativity. Carl Rogers, developer of non-directive psychotherapy, has stated that creativity is maximized under conditions of psychological safety and psychological freedom (25). Psychological safety involves accepting the individual as of unconditional worth, providing a climate in which external evaluation is absent and understanding the individual empathically. Psychological freedom involves giving the individual permission to be free but responsible for his actions. The program appears to meet these requirements and its structure and methods are very similar to client-centered therapy. The term student-centered teaching could easily be applied to this approach.

E. Paul Torrance has produced a more extensive list of principles for developing creative thinking through school experiences (28). Of the twenty ideas listed, nineteen have been intuitively developed to some degree in the University of Pittsburgh program. Giving information about the creative process is the only recommended practice which is not being followed. The teaching procedures for the program were developed without knowledge of the Torrance list.

Much of the recent creativity research is relevant to an evaluation of the program. Guilford has used the factor analytic approach to develop a theoretical model of intellectual aptitudes which contain 120 factors (14, 16). Most IQ tests measure seven or eight of these abilities and miss creative abilities completely (27). Getzels and Jackson report low correlations between IQ and creativity scores (11). They also report that teacher and peer ratings of creative students are lower than the ratings given high IQ students who were making the same grades.

Several researchers have investigated the personality correlates of creativity (1, 5, 19, 21, 27). In a summary of previous work, Torrance lists 84 of these (28). The most often-cited traits are autonomy (8, 24), independence in judgment (3, 25), femininity in interests and characteristics (24, 28), dominance (1, 8), complex integration of personality (4, 20, 26), openness to experience (2, 20, 25), tolerance of ambiguity (10, 28), and strong emotional drive (2, 13). There are indications that the undesirable traits which appear in creative children are the result of school and home environments which stifle creativity (11, 28).

They feel that our present school system does not provide for creative children as it should (11, 15, 17, 27, 28). Burton attributes this to an emphasis on the preservation of our cultural heritage rather than further contribution to it (7). Guilford has stated the needs most clearly in an address to Sacramento County educators (15):

"Opportunities for teaching creative skills are by no means limited to courses in art. Such opportunities are perhaps most obviously encountered in courses in the sciences, in composition, and in mathematics. In most subjects, however, including those just mentioned, we have been prone to think that the child needs to spend his first 16 school years in learning what others have done and have found out, leaving to the graduate-school level any serious encouragement for the student to produce something of his own. This policy will have to be materially changed, if we are to keep alive the natural creative inclinations with which the child starts at the bottom of the academic ladder. Some children, at least, could very well profit by having a part of their instruction in the form of seminars and some substitution of laboratory exercises of their own choosing for exercises that are ordinarily required.

"We need experiments that will also assess the possible benefits of teaching for creativity in connection with regular courses in sciences, mathematics, and the arts."

The University of Pittsburgh High School Science Research Program appears to be a possible answer to the needs which Guilford has pointed out. With this viewpoint and background, several hypotheses can be generated.

Table Showing Hypotheses, Tests to be Used, and Comments Justifying These Tests

The fundamental hypothesis is that the value of this method lies in its close relationship to methods recommended for fostering creativity.

Additional Hypotheses	Tests	Comments
1. If the program is teaching for creativity, certain personality changes may be produced.	Guilford-Zimmerman Temperament survey	Yields scores on 10 scales: a. general activity b. restraint c. ascendance d. emotional stability e. sociability f. objectivity g. friendliness h. thoughtfulness i. personal relations j. masculinity Career studies have shown that thoughtfulness and restraint differentiate between science and non-science careers for boys (9).
2. Aptitudes for creativity, as measured by the Guilford Tests, may increase during the program. The native abilities should not change, but personality changes "releasing" these abilities might be detected in the test scores.	Guilford Creativity Tests	There is some indication that creativity factors are not well differentiated in high school students and that the tests do not measure the same things in boys and girls (6). Another group of researchers has found that means and dispersions of scores from bright junior high students were similar to those found in Guilfords' studies with adults (23).

Additional Hypotheses	Tests	Comments
3. Since participation in the program generally represents work in addition to normal course requirements, an improvement in knowledge of subject matter and in the ability to use the subject matter is expected.	Sequential Test of Educational Progress (STEP) Science Battery	These tests stress ability to use science knowledge in solving problems (18).
4. The relationship between students and their scientist-advisors at the University should result in an increased understanding of scientists and scientific activity.	Test on Understanding Science (TOUS) Cooley & Klopfer	

The four tests will be given near the beginning and end of the summer and academic year, with alternate forms used in STEP Science and creativity batteries, to all students participating in the program. Students new to the program will be paired with similar students not participating in the program. The latter group will serve as a control. Pairing will be done within each school on the basis of sex, age, IQ, and grade point average. The control group will be tested at the same time students in the program are tested.

A second group of variables, dealing with the different conditions which exist within the program will also be analyzed. The extent of the program in each school will be measured using an index based on the number of participating students, with the number of students actually doing research or ready to begin research given greater weight. The amount of time the student spends at the University or in contact with people from the University will be recorded. The students' age, sex, and IQ will be taken into account. Significant relationships between variables in the second group and variables in the first group will be determined by multiple correlations. This analysis will be aimed at determining the best possible conditions within the program. It will also produce a better picture of the variation between schools and permit certain variables to be partialled out when relationships within the first group of variables are analyzed.

Another phase of testing will be an evaluation of teachers participating in the program. The teachers test battery will consist of the same Guilford creativity tests administered to the students and the Minnesota Teacher Attitude Inventory. In addition to this the teachers will be rated by the director and staff of the program according to the degree to which they follow the Teacher Guides in the Handbook of Research (12). This rating will be used as a criterion measure. The teachers will be

tested in the fall and spring when their students are tested.

Information from the evaluation will be incorporated into future plans and procedures for the program.

2. <u>Sequence of the experiment</u>

1. The battery of tests will be given to all students. Two lecture rooms at the School of Medicine will be used.

   a. All instructions given by test administrators in both rooms will be tape recorded as a check on uniformity.

   b. A sixty-minute battery of form creativity tests will be given to students in both rooms at 9:00 a.m. The tests will be Consequences, Match Problems, Plot Titles, and Unusual Uses.

   c. All students will be given a ten-minute break.

   d. At 10:10 a.m. students in one room will be given the Guilford-Zimmerman Temperament Survey and students in the second room will be given the Test on Understanding Science.

   e. At 11:10 a.m. students in the first room will be given the Test on Understanding Science and students in the second room will be given the Guilford-Zimmerman Temperament Survey.

   f. Between 12:10 p.m. and 1:30 p.m. there will be a break for lunch.

   g. At 1:30 p.m. students will be given part one of the STEP Science Battery (Sequential Test of Educational Progress). At 2:10 students will be given part two. Form 3A will be used for students in grades 7-9. Form 2A will be used for students in grades 10-12.

   h. Students will be dismissed at 2:45 p.m. Questions about the evaluation procedure will be answered at this time for those students who wish to stay. This question and answer session will be tape recorded. The answers given will not in themselves improve scores in the retest.

2. The teacher's test battery will be given to all teachers participating in the program. It will consist of the same Guilford creativity tests given to the students and the thirty-minute Minnesota Teacher Attitude Inventory.

3. The extent of the program during the academic year in each participating school will be determined bimonthly in October, December, February, and April. A weighted index will be used with values determined by students' progress. The index value for a school will

be completed as follows:

5 x the number of students performing or evaluating experiments.

3 x the number of students who have completed protocols and are ready to begin.

2 x the number of students writing protocols.

1 x the number of students reading and attending seminars who have not begun work on a specific problem.

SUM = Index Value

4. The office of the program will keep a record of the time each participating student spends at the University in conferences with advisors, or attending seminars and progress reports. University time is designed to be a measure of student contact.

5. The IQ's of the participating students and the control groups will be obtained from the schools and the tests on which the IQ's are based will be noted.

6. The director and staff of the program will rate participating teachers on eighteen of the aspects of research teaching given in the "Guides for Teachers" section of the Handbook of Research For High School Students and Teachers (12). Graphic rating scales will be developed and the reliability of the ratings will be tested.

7. The complete test battery will be given in May to all students who took the October tests and also to any new students who have been accepted for summer work in the program. The sequence followed will be identical to the October sequence except that alternate forms of the creativity tests and STEP Science battery will be used.

8. The teachers test battery will be given in May to all teachers who took the October tests and to any new teachers who have been accepted for summer work in the program.

3. Data Collection and Analysis

1. One data sheet will be kept for each student and teacher and information will be added as it is collected. (See Appendix B for sample data sheet.)

2. Students will be divided into three groups for the purpose of the analysis. Students with previous experience in the program who take the tests will constitute group one. Group two will consist of students entering the program when they take the tests. Group three will consist of the non-participating students paired with the entering students. These groups will be subdivided into boys' and girls' subgroups for each school.

3. Means and standard deviations for each variable in the test battery will be calculated for each subgroup in the three groups.

a. Analysis of variance for each variable will indicate significant differences between schools. As many subgroups as possible will be combined for further evaluation.

b. A comparison between groups one and two will give a rough estimate of the effects of experience in the program. It will indicate areas to examine closely when comparisons are made.

c. A comparison of the first test scores for groups two and three may indicate differences which caused the participating students to volunteer for research work.

4. The significance of relationships among the scores on the preliminary tests will be tested with Pearson product-moment correlations coefficients. Of special importance is the correlation between creativity tests and Guilford-Zimmerman scales. All possible relationships will be checked with the exception of those between the various Guilford-Zimmerman scores. The factor analytic method used in the construction of this test rules out significant correlations. Data from group one will not be used in these correlations.

5. The significance of relationships between age and the preliminary test scores and between IQ and the test scores will be tested. Data from group one will not be used.

6. The significance of relationships between the scores of teaching on the creativity tests and the Minnesota Teachers Attitude Inventory will be tested.

7. When further information is available a more complete analysis can be made. The second test battery scores will make it possible to compare the score changes in groups two with score changes in group three. This is the primary comparison.

8. A breakdown of score changes for each school will indicate schools in which the program had the greatest effect. Analysis of variance for each variable will indicate significant differences between schools.

9. A comparison of the score changes in group one with the score changes in group two will indicate the relative value of continued work in the program as opposed to just the initial impact. It is obvious, however, that several uncontrolled variables exist in the comparison. A more accurate assessment can be made by a later retest of these members of group two who continue working in the program.

10. The significance of the relationships among the students score changes will be tested.

11. The significance of the relationships between age and score changes and IQ and score changes will be tested.

12. The significance of the relationships between the extent of the program in each school and the mean score changes in each school will be tested.

13. The significance of the relationships between the time the student spends at the University and the student's score changes will be tested. Especially important is the relationship between University time and hypothesized TOUS test improvement.

14. The significance of the relationships among the teachers score changes will be tested.

15. The significance of the relationship between the staff ratings of teachers and the teachers fall test scores will be tested. The relationship between the ratings and score changes will all be tested.

16. Further analysis and partialling out of variables will be determined by the results of the analysis outlined above.

It is the opinion of the staff that further and continuing study of evaluation of the program is necessary. Portions of the above objective plan of evaluation are being used in one school (Baldwin), and from this study, it is expected that a revised plan can be used in the future in all participating research centers.

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Conclusions

Knowledge in the sciences is doubling every ten years because of the research that is being conducted in the scientific disciplines. The impact of this fact on education has resulted in the development of many new methodologies for improved learning.

Problem solving, or inquiry, with the need for background information, observation, measurement, and interpretation, has become the basis for teaching the sciences in many elementary and secondary schools. The opportunity to conduct original scientific investigations by teachers and interested students is the next step in the search for truth and knowledge, and allows for study in depth, for individual differences, and for development of creativity. The HSSRP serves as a model in educational methodology.

Observations:

Excitement in learning is evidenced by the majority of the participants. Students appreciate the opportunity to plan their own work and welcome direction and guidance by the teacher and consultant scientists.

Communication improves through the program activities in writing, speech, and questioning. Dialogue with peers, teachers, and scientists, and presentation of progress reports and summary sessions is aimed toward the improvement of communication.

The contacts with scientists inspire the young students of science to work, sometimes almost beyond their abilities.

Individualized instruction, using the research plan, allows for the development of each student according to interests and abilities. Creativity seems to develop spontaneously in the program. New developments are learned even before they reach the textbook level through lectures of ongoing research and the literature search.

Students do not like to evaluate themselves on the first attempt, but appreciate the opportunity before they have completed the program.

Curiosity by students is not very evident at the beginning of a program, but has become extensive before many weeks have passed.

Teachers who participate either become adventurous-spirited or can see no merit in the program.

New ways of making or using equipment are found in order to solve the problem.

The necessity for creative thinking is present and students respond in more detail than is expected of them.

The problems of a scientific research program have not all been solved. The major one is that of evaluation of the program and the individuals who

participate.

Another major problem is that of teacher recruitment in this kind of methodology. Most teachers are afraid to say "I don't know", yet this program is based upon the unknowns.

APPENDIX

Orientation Week

The orientation week lectures and other activities were planned to fit the needs of the student researchers. The protocols which had been presented for acceptance into the program were used as guides for these needs. The lecture topic list follows:

"Why Research"
"Research in Nutrition"
"The Library in Research"
"Immunology"
"Physical and Physiological Aspects of Contact Lenses"
"Molecular Biology"
"Data Collection and Interpretation"
"Statistical Evaluation Procedures"
"Plant Tissue Culture"

Workshops included:

Library usage and reporting
Scientist-advisor-student conferences
Use and care of the Microscope
Protocol writing and revision
Progress reports
Ecological technics

The scientists who participated were:

A. E. Axelrod, Ph.D., Associate Dean, School of Medicine
T. E. Cartwright, Ph.D., Associate Professor of Biophysics, Biology Department
*Charles Dickson, American Optical
*George Edinger, Bausch & Lomb
Mrs. Carolyn A. Gibson, Director HSSRP
Herman Langkamp, Research Associate, School of Dentistry
Joseph H. Sunder, Research Associate, Addison H. Gibson Laboratory, School of Medicine
*Harry Wachs, O.D., Director, Penn-Vision Institute

HSSRP Staff Members:
Mrs. Carolyn A. Gibson
Mr. John Bacon
Mr. Walter Jesteadt
Miss Nancy Jordan
Miss Beulah Frey

* Not associated with the University of Pittsburgh

Student Protocol

The attached protocol was written by a ninth grade student at Herron Hill Junior High School, Pittsburgh, Pennsylvania. This young man was one of the participants in the ecological program at Pymatuning and planned the study to be conducted on his return. He tried to conduct his experiment at the Schenley High School football field, near his home in a ghetto area, but found no chipmunks. Permission was granted by the Pennsylvania Game Commission, and the Pittsburgh Parks Service to conduct the experiment at Schenley Park.

The pilot study was completed, but needs to be repeated over a longer period of time so that significant results may be obtained.

TITLE: "Study of Chipmunk Territories in Schenley Park

Mark Stuckey - Grade 9. Herron Hill - 1965-1966

Rationale:

The chipmunk is a small, graceful animal, belonging to the rodent family. It is closely related to the squirrel, and lives in the eastern, central and western United States.

The chipmunk is only about 9 1/2 inches long, including the tail. He has a small, pointed brown head. Its hind legs are also brown, but its back and tail are dark gray. The chipmunk has a long mark on each side of its body with a long tan stripe in the middle and black around each of the eyes and on the tail. He uses his strong hind legs for hopping. The front legs are small and slender. The chipmunk uses his front feet like hands. The long nails of the front feet are good for holding food with flat, heavy teeth at the back of the jaw for chewing.

The chipmunk is active during the summer months. From October until April it stays in a hollow in the ground, eating nuts and grain it has stored.

Female chipmunks usually give birth to four or five young in May or June. Sometimes they bear another litter in August.

Chipmunks live about 2 1/2 years.

My study will be dealing with these animals. I plan to find out how many chipmunks live in a certain area and if they always stay in the same territory and other information that may be valuable in my studies of the animals. I plan to number the animals by Dr. C. E. Tryon's system (Technic # one). I also plan to mark the traps with brightly colored stakes. There will be many things to learn from these studies; following are a few:

a. What season of the year are chipmunks most active?
b. Do both males and females cover the same territory?
c. Are the animals more active in the morning than in the afternoon?

I plan to take the animal from the trap with gloves, clip the toes, put the number on record and release the animal. (I plan to put a stake in the ground every fifty (50) to seventy-five (75) feet and set one trap to a stake.) The traps will be checked every hour after they are set.

The graph I will use to number the animals is on the next page. The stakes will be colored brightly and numbered. Every time an animal is caught, I will number it and put it on record and record any other observations.

The traps are made from rectangle-shaped tin cans with the bottom on one side cut out. Small mouse traps are used to spring the trap door closed. On the mouse trap there is a piece of screen tied on to the small bar with thin strong wire. The screen is surrounded by metal to make the screen wire strong and sturdy; it also helps wire to keep its shape. Then there is a hole in the screen so that the rod can reach the lever that sets the trap off.

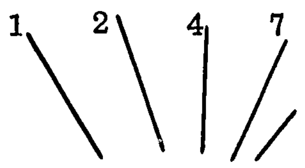
The end with the lever on it is nailed to the end of the tin can. Then holes are put in to the bottom on each side of the tin can, so that the wire bent into the shape of a loop can connect a string from the lever to a screen placed at the bottom of the can. The screen is held to the bottom of the can by thin wire. The bait is placed on the screen; when the animal steps on the screen to get the food the door slams closed.

Materials needed:

1. 8 rectangle shaped tin cans
2. nail clip
3. 8 wooden stakes
4. paint
5. wire screening (hardware cloth)
6. pair of gloves or a heavy sleeve
7. sunflower seeds (bait)
8. strips of metal
9. 8 small mouse traps
10. yard of thin wire
11. yard of strong string
12. note book
13. file cards
14. tape measure

-NUMBER GRAPH-

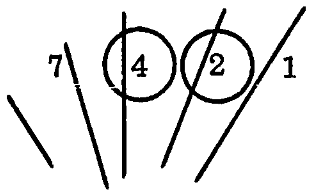
Thousands



Right Foot

Front Feet

Hundreds

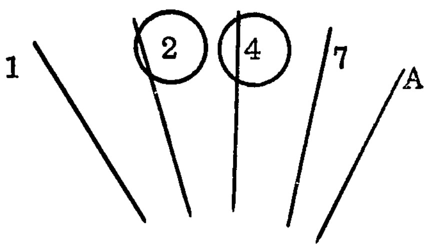


Left Foot

When feet are facing you

- - - -

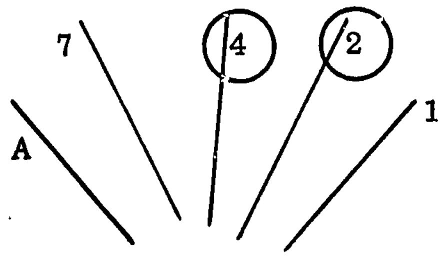
Letters



Left - Tens

Hind Feet

Ones



Right - Units

The circled toe nails are examples of nail clippings and what numbers they represent.

When two or more nails on the same foot are clipped add the numbers that each toe nail represents, the answer is how many hundreds, tens or ones there are on one hand. Add all the figures on the feet together and that is the number of the animal. The numbers are always before the letters.

EXAMPLE:

Hundreds	200 + 400 =	600
Tens	20 + 40 =	60
Ones	2 + 4 =	6
No. of Animal - - - - - - - - - -		666

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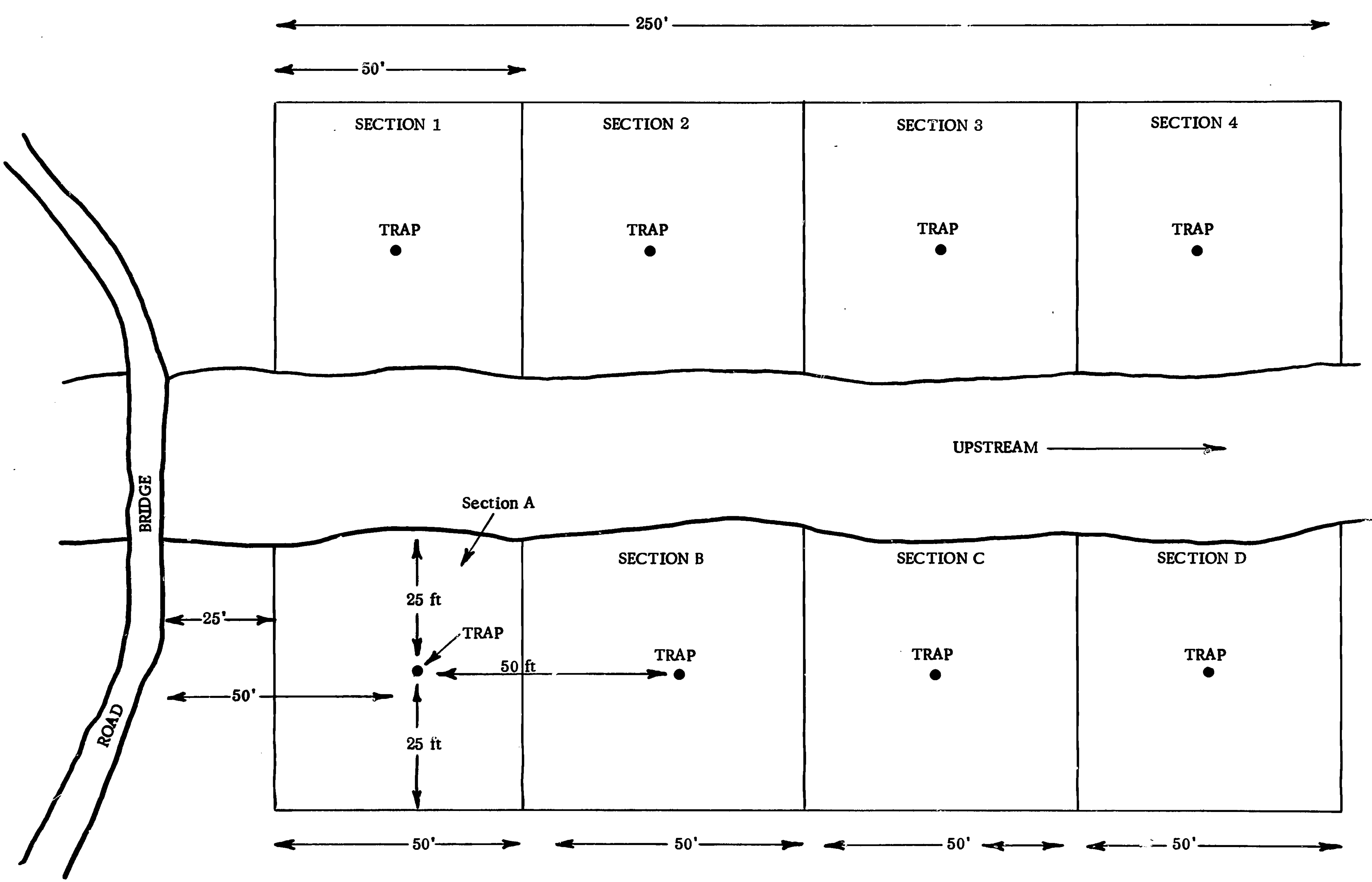
Verrile, Hyatt. "Strange Animals and Their Stories", L.C. Page & Co., Boston, Mass., 1939.

Sanderson, Ivan T. "How to Know American Mammals", Little, Brown & Co., Boston, Mass., 1951.

Teale,Edwin. "Circle of the Season", Vail-Ballou Press, Inc., New York, 1956.

Teale, Edwin. "Autumn Across America", Dodd, Mead & Co., N.Y.

PLAN FOR PLACING TRAPS



Cooperative Scientist-Student Project

Dr. Erston V. Miller, Professor of Biology, University of Pittsburgh reported on one of his ongoing research projects during a Saturday seminar for high school students. He invited any interested students to conduct the same experiment under his direction.

The topic of his research was Investigations on the Effect of Molybdenum on the Growth of Tomato Plants. Seven students from three high schools wrote protocols after their literature search, and set up the experiment in their schools. Three seminars were conducted with this small group by Dr. Miller. The results were written into final reports by all the students and presented to Dr. Miller, who added the date to his study. The total findings were reported back to the investigators for their conclusions.

TABLE SHOWING RESULTS OF MOLYBDENUM STUDY

Team Number	Height of Plants (cm.)		Fresh Wt. (gms.)		Dry Wt. (gms.)	
	Control	Treated	Control	Treated	Control	Treated
1.	15.80	15.53	2.77	3.02	0.285	0.413
2.	32.70	31.50	7.00	9.70	0.720	0.760
3.	3.17	5.08	2.30	2.58	0.490	0.540
4.	11.80	20.40	---	---	---	---
5.	18.20	20.25	9.50	10.50	1.050	1.260
Average	16.33	18.55	5.39	6.45	0.636	0.743

Research Science with Emphasis on Biology

The methodology which developed as a result of the summer and club activity is now being developed into the curriculum of several schools. It is particularly applicable to the second year biology courses and has been shown to be usable in beginning courses of biology. (pages 14-15)

Behavioral objectives are being developed, suggested lessons for achieving these objectives are being used according to the outline in the following pages. The teacher presents the research procedures (column 1), and then implements each one with an activity for gaining understanding. Students are encouraged to select an area for investigation, these are analyzed, and the information involved in column 2 becomes the subject-matter for the class. The technics listed in column 3 become the class laboratory practice, so that students are prepared to conduct an original experiment sometime during the academic year.

Outline of Research Procedures, Factual Information Needed to Develop Understandings, and Technics Needed to Conduct Original Scientific Investigation

Research Procedures

I. What is original scientific investigation?

- A. Basic versus applied research
  1. Historical developments in the sciences
  2. Examples of research applied to specific disciplines
- B. Ideas for research problems
  1. Ongoing research
     - a. From periodicals
     - b. From scientists
  2. Observations
     - a. From the environment
     - b. From readings
- C. Selection of area for investigation
  1. Reading for foundations
  2. Reporting
  3. Formulation of problem
     - a. Definitive title
- D. Survey of literature
  1. General information
  2. Specific information on past experimentation

Development of Understandings in Biology

I. What is science?

II. What is biology?

- A. The Biosphere
- B. Ecosystems
- C. Functions of living organisms

III. The Cell

- A. Anatomy & physiology
  1. Organelles
  2. Life functions
- B. Differentiation in cells
  1. Sizes, shapes, kinds
  2. Abnormalities
  3. Functions
  4. Plant and animal cells

IV. Chemistry needed to understand biology

- A. Elements found in protoplasm
- B. Structure of the atom
- C. Compounds and mixtures
- D. Formulas and equations
- E. Solutions
- F. Carbohydrates and proteins
- G. DNA and RNA
- H. Energy
- I. Chemistry and biological functions

Technics

I. The science notebook

II. Use of the Library

- A. Finding materials
- B. Reporting on generalized readings
- C. Abstracting
- D. Literature survey
- E. Reports on technical readings

III. Scientific writing

IV. Observation & measurement

V. Data collecting and recording

VI. The microscope

- A. Kinds, care, use of
- B. Temporary and permanent slides

VII. Photography

VIII. Good Housekeeping

- A. Glassware
- B. Classroom
- C. Care of living organisms

IX. Sterile technics

E. Writing rationale
   1. Reason for experiment
   2. Review of work of past
      a. literature search
   3. Report of lectures
   4. Advisor discussions

F. Designing the experiment
   1. Choice of methods
   2. Sequence of experiment
   3. Planned data collection
      a. Design of data sheets
      b. Types of observations to be made
   4. Materials list
      a. Quantities and specifications

G. Progress report and/or conference for approval

H. Conducts experiment
   1. Follows protocol exactly
   2. Records observations
   3. Measures accurately
   4. Discussions
   5. Analyzes data statistically
   6. Interprets results

I. Final Report
   1. Title
   2. Rationale
   3. Protocol
      a. Sequence of experiment
      b. Addenda

1. Respiration and fermentation
2. Photosynthesis
3. Digestion
4. Metabolism
5. Catalysts and enzymes
6. Auxins and hormones
7. Immunity-antigens and antibodies
8. Osmosis and diffusion

V. Genetics

A. Heredity and environment

B. Reproduction
   1. Mitosis and meiosis
   2. Chromosomes
   3. Fertilization
   4. Sex determination
   5. Embryo development
      a. plants
      b. animals
   6. Regeneration
   7. Mendel's laws
   8. Other genetics
   9. Phenotypes and genetypes
   10. Strains

C. Diversity

D. Development

VI. Behavior

A. Plants

B. Animals

A. Autoclaving

B. Filters

C. Personal

D. Surgery

X. Animal studies

A. Culture methods

B. Cages

C. Numbering systems

D. Necropsies

E. Anatomy

F. Growth rates

G. Vaginal smears

H. Control of environmental factors

XI. Plant studies

A. Propagation

B. Hydroponics

C. Soils

D. Control of algae, fungi, bacteria

E. Culture of micro-organisms

c. Data
d. Data analysis
e. Observations
f. Materials list

4. Discussion
5. Conclude or repeat
6. Literature cited

J. Summary Session

F. Control of environmental factors

XII. General technics

A. Chromatography

B. Electrophoresis

C. Blood

D. Distillation and de-eminizing

E. Glassworking

F. Determination of pH

G. Anaesthetics

Evaluation of Student Progress in the Research Method of Teaching

The development of thinking individuals who are able to express their thoughts and report their work is a major aim of the research program. The ability of a student to exchange ideas with his peers, teachers, and advisors is of major importance. One phase of this development involves the presentation of progress reports both during the summer and academic school year in an attempt to determine the progress in organization of information and of communication. The compilation of a final report is also requested when the student has completed his problem, although student development as shown during the progress of the experimentation and solving of the research problem is the primary consideration. Evaluation of subject matter achievement (background of the problem) is considered part of the total evaluation and is included in the sections on readings and discussions.

The attached evaluation of progress includes all the phases through which the student progresses, and allows for self-evaluation by the student as well as evaluation by the teacher and the scientist who served as advisor. If there are major differences in these opinions, then a conference between the people involved becomes a teaching technic which should lead to better understanding of the procedures involved in research methods.

The criteria for judging the progress of students who are conducting original scientific investigations must include how well the student follows the research procedures. A flexible plan must be followed because each student works at his own pace. Self-judgment is important, but if the program is to function as a student-teacher-scientist cooperative understanding, a comparison of the evaluations must be made.

Student's Name ______________________________ Date ____________
Title of Problem ____
____
Evaluator's Name ________________________ Position ____________
(Student, Teacher, Scientist)

On the following pages are listed several procedures in which students have been oriented to use as guides while planning and conducting original scientific investigations. On the line scale following each procedure place a vertical mark to indicate your estimate of the accomplishments of the student. Place only one mark on each. Any uncompleted areas are not to be marked.

Sample and line scale:

LOW HIGH

Survey of literature - - - - - - - - - - - - ______________________

If the survey is good, mark as shown here:

LOW HIGH

Survey of literature - - - - - - - - - - - - ________________/_____

If the literature search is too general, mark as shown here:

Survey of literature - - - - - - - - - - - -	LOW / HIGH
	/

If the survey is partially complete, but reflects general and specialized literature, mark in an appropriate position between the extremes:

Survey of literature - - - - - - - - - - - -	LOW HIGH
	/

A point system to serve as a way of comparing the opinions and observations is an aid to the evaluators. Place the template over the line scale to determine the total points for each item. This system will enable the student who has read widely to be judged equally with the student who has learned many technics when points are totaled.

Student's Name ______________________________
School ____________________ Sponsoring Teacher ____________
Title of Problem ______________________________

	LOW HIGH
I. Participation in lecture and discussion sessions.	
A. Did you attend and benefit from lecture-discussion sessions and conferences with advisors?	____________
1. How many lectures did you attend? _____	
2. How many conferences did you have with	
a) your teacher? _____	
b) your advisor? _____	
c) staff of HSSRP _____	
B. Did you participate by asking questions in lecture and conference sessions?	____________
C. Did you attend and benefit from other science lectures, seminars, at the University of Pittsburgh, or Penna. Junior Academy of Science Series?	____________
1. How many? _____	
II. Supplementary reading	____________
A. How much reading did you do on your own? (library and science journals)	____________
B. Did you explore several areas of science that are related to your problem?	____________
C. Did you write accurate abstracts? How many? _____	____________
D. Did you keep your abstracts in duplicate?	____________

E. Did you use what you learned through your reading in planning your experiment? | LOW ________ HIGH
F. Did you discuss your readings with other students and with an advisor, asking questions about your reading? ________

III. Planning the research problem ________
A. Does the title define the conditions of your investigation? ________
B. Does the rationale explain the basis for your experiment? (previous work and the reasoning behind your problem) ________
C. Is the rationale written in clear and concise scientific style? ________
D. Is the sequence of experiment in a complete and easily followed step-by-step order? ________
E. Are the needed laboratory technics described in detail? ________
F. What methods of random selection of the organisms were indicated? ________
G. What measurements and observations are planned? ________
H. Is the materials list complete? ________
I. Did you design a specific experiment to test your hypothesis, keeping variables at a minimum? ________

IV. Conducting the experiment
A. Did you present a progress report of your planned experiment? ________
B. If necessary, did you make changes in your protocol after discussing them with your teacher or advisor? ________
C. Did you follow the procedure outlined in your protocol? ________
D. If you made changes in your procedure, did you write an addendum? ________
E. Did you record observations and data accurately? ________
F. Did you use photographs or diagrams whenever possible? ________
G. Did you keep the laboratory, animal room, and your records neat and clean? ________
H. Did you observe rules of T.L.C. in your work with the experimental organism? ________
I. Did you continue reading about your problem and related ones during the conduction of the experiment? ________

	LOW	HIGH
V. Analysis of results		
A. Did you compute statistical averages and tests?		
B. Did you submit supportive tables and graphs?		
C. Does the discussion of the analysis show understanding of the statistical evaluation?		
D. Did you interpret results and observations and try to explain why they were obtained? i.e., did you formulate hypotheses to explain results?		
E. Was the conclusion stated on the basis of the statistical evaluation?		
VI. Original thinking		
A. Did you reason out possible expected results before actually obtaining results from your experiment?		
B. Is the reason for conducting the experiment (hypothesis) the result of your own thinking?		
VII. Progress reports and summary sessions		
A. Were your reports well organized and presented in scientific style?		
B. Did you contribute to and benefit from discussions of other students' work?		
C. Did you enjoy doing your own research?		
VIII. Bibliography		
A. Did you follow a correct form on reporting your readings?		
B. Are the references arranged in alphabetical order?		
C. Are the references annotated in the rationale?		

COMMENTS --
STUDENT ______________________________

Would you like to continue doing your own research on this problem or any other? If so, explain briefly what you would like to do.

COMMENTS --
TEACHER OR ADVISOR ______________________________

What suggestions have you for improvement?

Evaluator ____________________

Statement by a Student

on

THE ROLE OF SCIENTIFIC RESEARCH IN THE HIGH SCHOOL

Barbara Butala, 12th Grade
West Mifflin North

My topic is "The Role of Scientific Research in the High School", but before I begin, I'd like to explain exactly what research means to us in the program.

It means, first, to select a completely original topic. Then, we must design an experiment concerning this topic. Finally, we must complete the experiment according to the design. All of this is carried out with the aid of scientist-advisors from the University of Pittsburgh.

Both the topic and the experiment must be original. I have been told that much of the work in the program today is comparable to investigations being carried on throughout the scientific world.

The role of research in the high school is, I believe, to teach us to think as scientists think. This may seem easy, but if you have really listened to a scientist, or talked to one, or have asked one questions, or have had one question you, you soon realize that scientific thinking and everyday thinking are very much different.

A scientist must be analytical and objective. He must not accept things blindly, and he must be able to ask the questions "How" and "Why?"

Questions are a very important part of the program, but most of the questions we ask our scientists and advisors are not directly answered. Sometimes we are directed to a source in the library where our answers can be found. More often, we are pushed into a line of thinking through which we can arrive at the answers for ourselves by reasoning and relating.

Oddly enough, the directors and teachers of the program are not too concerned with the individual outcome of each experiment. They are not overly interested in the effects of a certain hormone on the growth rate of certain cells as we, the students, are. They are primarily concerned with the effects of researching on the experimenter. They want to know if his patterns of thinking have changed from the beginning of his research work to the completion. They want to know if he has learned to reason and to relate and to think as a scientist does.

The benefits of participating in a program such as this are many. We have the opportunity to meet many people, both scientists and students. We can learn complex and advanced techniques. We have experience in completing an extensive literature survey. We are afforded an opportunity which few other educational programs can offer. But, in my opinion, the most important benefit is that we learn to truly appreciate our surroundings. We begin to understand how complex our world is, yet within this complexity there is a constant order. We learn this through scientific reasoning, relating, and thinking.

OE 6000 (REV. 9-66) DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

OFFICE OF EDUCATION

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RETRIEVAL TERMS

600 High School Science Research

601 Lectures and Seminars

602 Ecological Foundations

603 Junior High School Foundations for Research

604 Inservice Training for Teachers

605 Curriculum Development in Biology

606 Student Evaluation

IDENTIFIERS

607

ABSTRACT The University of Pittsburgh High School Science Research Program enables teachers and students to learn research procedures by conducting original scientific investigations. The program structure includes the selection of an area of investigation; conduction of a literature search; identification of a problem; writing a protocol, including the rationale, sequence of experimentation, data collection plan, materials list; followed by the actual experimentation, analysis and reporting of results. Ideas for research, foundations in subject matter, laboratory and analysis technics are presented by the staff and/or scientists in the form of lectures, seminars, small group and individual conferences. The experimentation is conducted in the participating high schools.

An orientation week in June, at which time lectures, laboratory and library workshops, protocol writing and progress reports are scheduled, develops attitudes toward research. Following the week at the University, junior and senior high students return to the high schools to conduct their planned experiments under the guidance of the teacher and with the advice of scientists. A selected group of students and teachers attends a 2-week session at the University Ecology Laboratories at Pymatuning Lake to learn ecological technics to be applied later on school sites. Another group attends a workshop in tissue culture at the Graduate School of Public Health at the University.

Work that is not completed continues into the academic year as class or club activity. Progress reports and scientist lectures are scheduled, motivating more students and teachers in research activity.